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TILL PARAMETER: A NUMERICAL EXPRESSION OF TEXTURE ENABLING LABORATORY CLASSIFICATION OF TILL

by

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INTRODUCTION

The "Comminution Parameter" was derived from the results of Grain Size Analyses. Continuous curve plots show the relationship of the quantity of grains (expressed as weight percentages) to their respective grain sizes (expressed in millimeters) throughout the ranges of sands, silts, and into the clays. This grain size span is from 2.0 mm to .001 mm, and this size fraction for till is known as the till matrix.

The method for analyses "Granulometric Analysis with an Automated Particle Size Analyser" was described by Ross (1979). The sands are fractionated by dry sieving, and the Sedigraph (5000D) is used to determine the fractions of silt and clay. The results are presented on a "composite graph" which shows two continuous curves, the one being the grain size distribution, and the other the cumulative weight percentage (passing) curve. They are illustrated by Figure 1. The curves are continuous from 2.0 mm to 0.001 mm, thus enabling measurement abundance and size throughout the sand, silt, and into the clay fraction.

The cumulative weight percentage curves for 85 till analyses were assessed and the mean value of the Comminution Parameter was determined to be $C^{.0880}\pm^{.0777}$. The acceptable limits, with 95% confidence, are from 1.2173 to 0.8895 (i.e. within 2 standard deviations).

By definition, when the numerical value of the comminution parameter falls within the limits 1.2173 and 0.8895, the parameter is named the Till Parameter, and when the value is outside the Till Parameter limits as it is for sediments other than till, it is named the Comminution Parameter.

PREVIOUS INFLUENTIAL RESEARCH

Early metallurgist, Goudin et al., 1926, defined the 'law of crushing' of crystalline rocks by mechanical means. It states, "– the percentage of weights of grains of various sizes and these sizes themselves follow a definite law."

The end product of till is, in part, fragments of crystalline rocks which have been reduced by glacial erosion, and this phenomenum led to the investigation of till texture.

The results of grain abundance – size studies of till matrices, showed the abundance – size, relationship of grains within one size range to have the same abundance – size relationship within another equisized range.

This identical abundance – size relationship for several ranges of identical size–implies that the end product of till, comminution by glacial erosion (mechanical disintegration) simulates the product of comminution by mechanical grinding; the identical results of comminution implies the two products are similar.

TERMINOLOGY

Abundance – Size relationship measured between adjacent ϕ units,

ϕ_B = $\ln_2$ diam. of grains at B

ϕ_A = $\ln_2$ diam. of grains at A

General formula for calculating Comminution Parameter is, as follows:

$$P_c = \bullet^{\ln \frac{A}{B+d}} - {}^{1.049}(\ln B)$$

P_c – comminution parameter

A – abundance of grains, expressed as weight percent, at coarse limit of measured grain size interval (value interpreted from wt. percent cumulative curve).

B – abundance of grains, expressed as weight percent, at fine limit of measured grain size interval (value interpreted from wt. percent cumulative curve).

d – diameter of grains, expressed in millimeters at fine limit of measured interval.

K_t – Till Parameter = P_c when numerical value of comminution constant is between 1.2137 and 0.8895

FORMULA VARIABLES

The values of the variables, abundance–size and grain size, are interpreted from the continuous grain size distribution curve which is the end result of a grain size analysis (Ross, 1979). These variables are measured within grain size intervals, and the range of an interval is chosen to be one ϕ dimension with the size limits expressed in millimeters.

The method for determining the two variables, is as follows:

(1) Range Size – it is expressed in millimeters, and it is the grain size of the lower limit of the measured interval.

(2) Abundance–size – interpret the cumulative weight percentage for each grain–size limit of a measured interval and express the abundance of the interval by the ratio of the cumulative weight percentages using the larger percentage as the numerator and the smaller as the

denominator. Divide the abundance ratio by the range size which eliminates the continuous slight increase in value of the ratio with decrease in grain size.

DERIVATION OF THE FORMULA FOR THE COMMINUTION PARAMETER (P_c)

The procedure was, as follows:

(1) Determination of the two variables, abundance–size and range size, were measured from the cumulative curve of each granulometric analyses; the measurements were interpreted for several adjoining size ranges.

Abundance–size Variable –

Cumulative weight % of coarse limit of range (A)

Cumulative wt % of fine limit of range (B) x (grain size in mm. of fine limit of range (d))

Range size variable –grain size in mm. of fine limit of range

(2) Plot of the Variables – Paired variables, i.e. Abundance–Size and Range Size were determined for several ranges of several granulometric analyses. The points were plotted on a log–log graph, i.e. Abundance–Size versus Range Size. The points were joined and the resultant curve was a straight line with the y intercept being the comminution parameters. Figure 2 is an illustration of the 'Parameter Curve'.

(3) Equation of Curve was calculated – (using algebraic format)

$y = mx + b$

$$P_c = \ln \frac{A}{Bxd} - (1.049 \times \ln B)$$

The variables of A, B, and d for any analyses may be measured, and the value of P_c is calculated.

P_c is the 'Comminution Parameter'

DETERMINATION OF TILL PARAMETER

Eighty–five tills were processed, and the P_c value was calculated to be a constant value, within narrow limits, i.e. 1.2137 to 0.885.

When the numerical value of the Comminution Parameter is within the limits of a till, the Parameter is then named the Till Parameter.

RECORD OF COMMINUTION PARAMETER DETERMINATIONS

It is important to record all measurements and calculations for the comminution evaluations, P_c and K_t.

The record used by the laboratory which has proved satisfactory is shown by Figure 3.

SIMPLIFICATION OF PROCEDURE FOR DETERMINATION OF THE COMMINUTION PARAMETER

* Subdivide the ranges, to be measured, into equal logarithmic dimen–sions by choosing the range limits at the ϕ boundaries. (With reference to Figure 1) choose ranges, as follows:

ϕ range	Equivalent mm range
−1 to 0	2.0 – 1.0
0 to 1	1.0 – 0.5
1 to 2	0.5 – 0.25
2 to 3	0.25 – 0.125
3 to 4	.125 – .0625
4 to 5	.0625– .0313
5 to 6	.0313– .0517
6 to 7	.0157– .0079
7 to 8	.0079– .0039
8 to 9	.0039– .0020
9 to	.0020– .0010

* Manual calculations are simplified by using the values listed in Table 1 for the end segment of the formula (1.049 x ln B).
* Use the record sheet, Figure 3, for entry of measurements. The columns are arranged in an order sequence so that calculations become routine, and the end results are easily obtained.
* A programmed computer simplifies calculations.

CONCLUSIONS

The numerical evolution of the Comminution Parameters, and the corresponding Till Parameters hinge on the measurements made from the weight percent cumulative curves which are the complete presentation of the results from a granulometric analyses.

* The Till Parameter, K_t, permits an accurate laboratory classification of till, and also the differentiation of till from other unconsolidated sediments.

* The Till Parameter is indirectly a measure of the till texture. The breakdown of rocks (comminution) by processes of glacial erosion results in a constant relationship between the abundance of grains and their respective grain sizes.
* Within the till matrix which spans from 2.0 mm to infinitely small grains, when two or more ranges of ϕ unit dimensions conform to the Law of Crushing, (K_t values between 1.2173 $\rightarrow$ .8895 mm), then the sediment is classified as a Till.
* The size distribution frequency curve for a till is always distinct and ascertainable. It was explained by Goudin (1926) to be a feature of the grain fragments – the end product of mechanical grinding. Photo–graphs of a crushed rock showed two types of cracks that produced two distinct sizes of grains; the transverse cracks produced larger whereas the radial cracks produced smaller grains. This polymodal feature of till, the product of comminution, supports the hypothesis that till grains, reduced by the process of glacial erosion, simulate the comminution of rocks by mechanical grinding.
* Till is defined as that part of glacial drift consisting of material deposited by and underneath the ice, with little or no transportation or sorting by water; it is generally an unstratified, unconsolidated, heterogeneous mixture of clay, silt, sand, gravel and boulders.

A supplement to the above standard definition which is based on the results of laboratory textural studies, is as follows:

"A portion of the consistent grains of till, within the sands, silts and coarse clays, are the product of comminution of crystalline rocks by the glacial erosional process of mechanical disintegration, and there exists a relationship between the abundance of grains and their respective sizes."

REFERENCES CITED

Ross, W.C., 1979, Granulometric Analysis with an Automated Particle Size Analyser, Circ. 15, SRC Report No. G79–10.

Goudin, A.M., 1926, An Investigation of Crushing Phenomena, American Inst.: Mining, Metallurgical and Petroleum Engineering, Transactions No. 73, pp 253–317.

Table 1. Pre–calculated Values of the Formula Segment – (1.049 x d).

formula $K_c = \ln \frac{\text{cum a}}{\text{cum b x d}} - (-1.049 \times \ln d)$

Standard values for (–1.049 x ln d)

when d = 1.0	; (–1.049 x ln 0)	=	0
0.5	; (–1.049 x ln .5)	=	– .7271
0.25	; (–1.049 x ln .25)	=	–1.4542
0.125	; (–1.049 x ln .125)	=	–2.1813
0.0625	; (–1.049 x ln .0625)	=	–2.9084
0.0313	; (–1.049 x ln .0313)	=	–3.6356
.0157	; (–1.049 x ln .0157)	=	–4.3576
.0079	; (–1.049 x ln .0079)	=	–5.0781
.0039	; (–1.049 x ln .0039)	=	–5.8186
.0020	; (–1.049 x ln .0020)	=	–6.5191
.0010	; (–1.049 x ln .0010)	=	–7.2426
.0005	; (–1.049 x ln .0005)	=	–7.9733

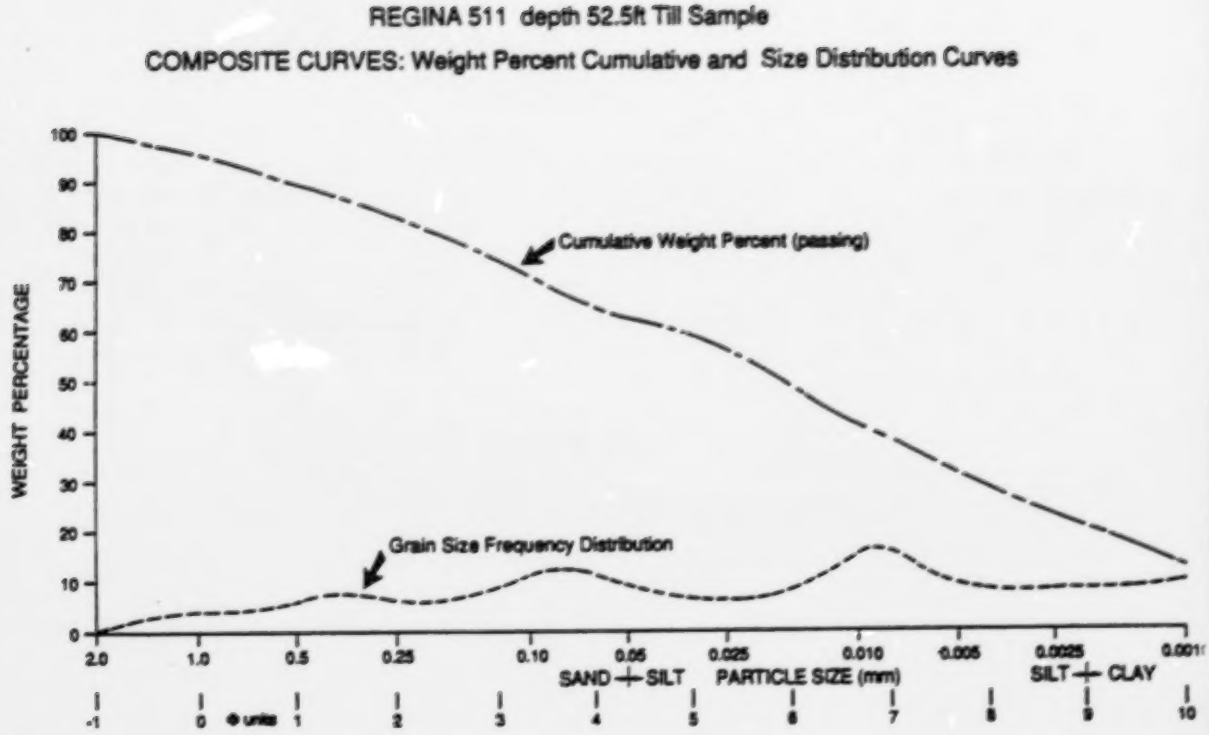

Figure 1. **Composite Curves: Weight Percent Cumulative and Size Distribution Curves**

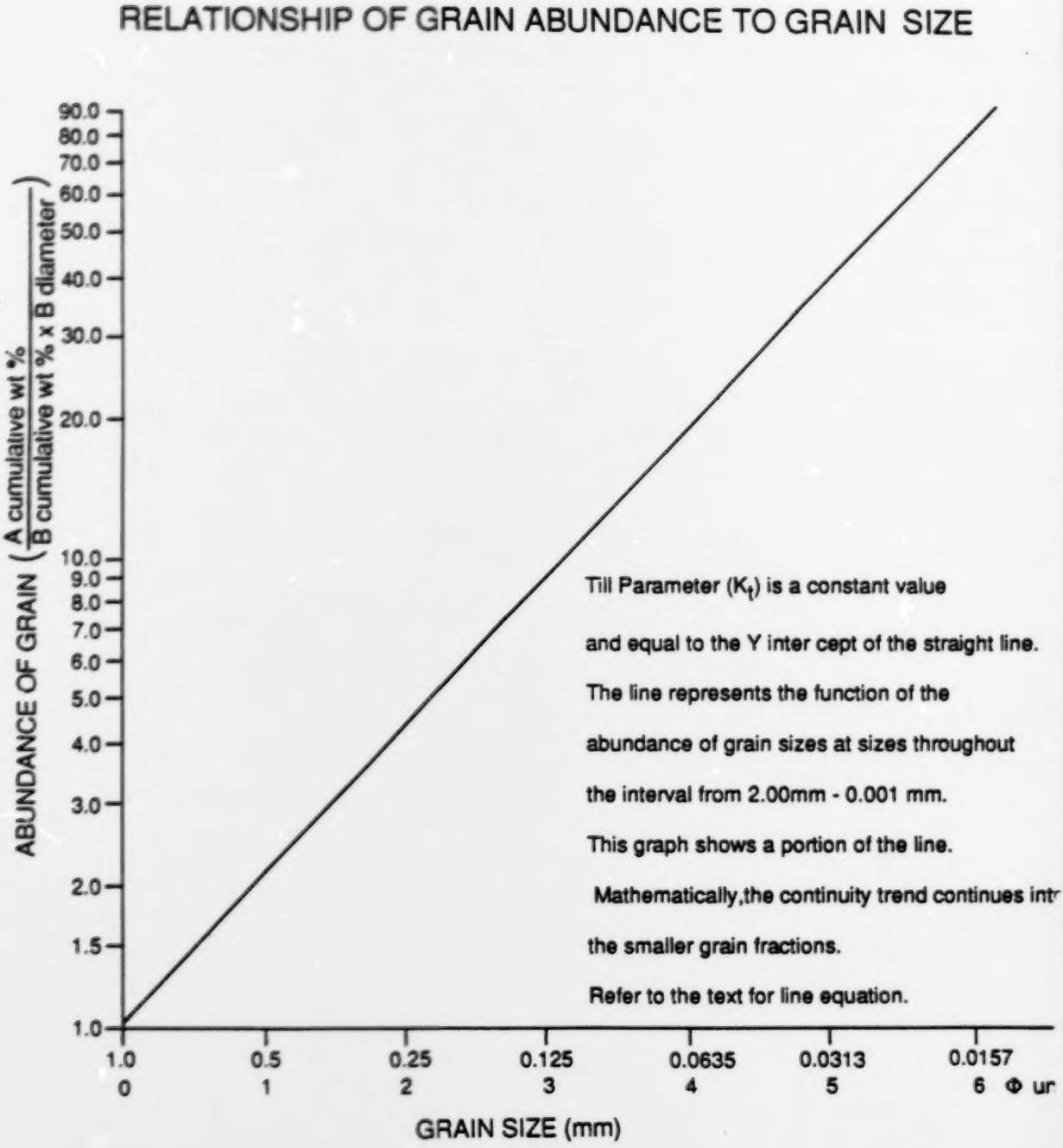

Figure 2. Relationship of Grain Abundance to Grain Size

Figure 3. Pc - Kc Comminution Record Sheet

Sample Name: Regina 511, depth 52.5 ft, date June 23/86					
Measured interval	**Abundance-size**	**Range size**	**Pc**	**Kc (1.2137-0.8895)**	**Till**
2.0 – 1.0 mm	$\frac{100.0}{95.8 \times 1.0}$	1.0	2.8401	Kc ≠ Pc	No
1.0 – 0.5 mm	$\frac{95.8}{89.9 \times .5}$	0.5	1.0312	Kc = Pc	Yes
0.5 – 0.25 mm	$\frac{89.9}{83.2 \times .25}$	0.25	1.0096	Kc = Pc	Yes
0.25 – .125 mm	$\frac{83.2}{74.0 \times .125}$	0.125	1.0154	Kc = Pc	Yes
0.125 – .0625 mm	$\frac{74.0}{64.7 \times .0625}$	0.0625	3.354	Kc ≠ Pc	No
.625 – .0313					
.0313 – .0157					
.01578 – .0078					
.0078 – .0039					
.0039 – .0020					
.0020 – .0010					